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COST-SIZE RELATIONSHIPS FOR CASH CROP FARMS IN YOLO COUNTY, CALIFORNIA

Gerald W. Dean and Harold O. Carter

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FOREWORD AND ACKNOWLEDGMENTS

This is the first report in a series of studies in different farming areas of California, focusing on the relationship of costs to the scale of farming operations. The primary data on which this study is based were obtained from a sample of farmers in the cash-crop irrigated area around Woodland in Yolo County.

The authors acknowledge the assistance and cooperation of the Yolo County farmers who provided the basic information used in this study. Valuable assistance also was received from Mr. T. S. Torngren and Mr. M. P. Zobel of the Yolo County Farm Advisor's Office, Dr. John Lingle of Vegetable Crops, and Mr. Jack Hills, Dr. Milton D. Miller, Mr. Philip Parsons, and Dr. Doyle Reed of the California Agricultural Extension Service. John Allison, Warren Johnston, Robert Leonard, and John Vondruska carried out the field work and made preliminary analysis. Clement Hartley, Larry Sweringen and Adrian Vasquez of the Agricultural Economics Statistical Pool assisted at various stages of the analysis.

COST-SIZE RELATIONSHIPS FOR CASH CROP FARMS IN YOLO COUNTY, CALIFORNIA

by

Gerald W. Dean[1] and Harold O. Carter[1]

INTRODUCTION

Historical trends of farm size in California indicate important increases in the past and suggest the hypothesis of increasing farm size in the future. Farm size, however measured, has increased rapidly in California since 1940. Table 1 indicates that farm size, as measured in acres per farm, increased substantially in every crop reporting district in California between 1940 and 1954.[2] As a state average, the land per farm increased by one-third from 230 acres to 307 acres. This change in size is due primarily to consolidation of existing farms into larger units. Table 2 indicates that the proportion of farms in every size category over 180 acres increased since 1940; the proportion of farms in every category under 180 acres (except less than 10 acres, due to part-time farming) decreased since 1940. Farm size can probably be measured more accurately by value of product sales than by acres alone. Expressed in constant dollars, the value of product sales per farm in California was $4,908 in 1940, $6,373 in 1945, $6,417 in 1950 and $8,239 in 1954.[3] This trend toward larger farms has caused speculation that ultimately

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[2] While census data on farm size is available only through 1954, the 1959 census is expected to reveal a continuation of the trends noted.

[3] Hopkin, John A., A Study of Farm Size in California, Economics Department, Bank of America, N.T.& S.A., San Francisco, California. (Unpublished manuscript.) 1957.

TABLE 1

Average Acreage per Farm by Crop Reporting Districts, California, 1940-1954

Area	1940	1945	1950	1954
	acres			
Crop reporting districts:				
I-North Coast	438	454	546	566
II-North Central	514	613	767	847
III-North East	1,007	949	1,079	1,165
IV-Central Coast	236	250	267	286
V-Scaramento Valley	323	312	326	350
VA-San Joaquin Valley	215	284	278	293
VI-Mountain Area	422	476	469	581
VII-Southern Calif.	117	115	132	192
State	230	252	267	307

Source: U. S. Census of Agriculture, California. 1940, 1945, 1950, 1954.

TABLE 2

Percentage of Farms, by Size, California, 1940-1954

Size of Farm	1940	1945	1950	1954
	percent			
Under 10 acres	23.8	26.9	27.3	27.7
10 to 29	28.5	26.8	26.2	24.8
30 to 49	12.5	11.7	11.6	11.3
50 to 99	11.5	11.2	11.2	11.1
100 to 179	8.0	7.9	7.5	7.7
180 to 259	3.4	3.3	3.3	3.6
260 to 499	4.9	4.6	4.8	5.0
500 to 999	3.4	3.3	3.4	3.7
1000 and over	4.0	4.3	4.5	5.1
Total	100.0	100.0	99.8	100.2

Source: C. O. McCorkle, Jr., A Statistical Picture of California's Agriculture. California Agricultural Experiment Station Circular 459.

only extremely large scale farms will remain in California agriculture. The underlying hypothesis of such speculation is that considerable cost economies are realized through expansion of farm size. Development of expensive machinery which can be justified only on large acreages, labor specialization, and buying and selling economies are often cited as reasons supporting the "inevitable" shift to extremely large-scale farming in California.

More exact knowledge of the relationship between costs and size of operation is of importance to a number of different groups--farmers, bankers and leaders of other agriculture-related industries, and administrators of state and national governmental agencies. Farmers need to know the size or scale of operation required in order for them to compete successfully with other farms in the long run. As farms expand in size, machinery, chemicals and capital in other forms substitutes for labor. Thus, banks, fertilizer and machinery companies and other groups furnishing agricultural inputs have a direct interest in economies of scale and trends in farm sizes. Larger, more commercialized farms also tend to develop integrated production and marketing practices which exert an important impact on the processing and marketing of agricultural products. Finally, knowledge of the economics of farm size is necessary as a basis for governmental policy, such as determining acreage limitations in water development programs.

Despite the continuing need for knowledge of economies of size in California agriculture, only a few empirical studies are available.1/ Therefore,

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1/ See: McCorkle, C. O., Jr., Northern Kern County Cotton-Potato Farms, Costs, Returns and Scale of Operations. Calif. Agric. Exp. Sta. Giannini Found. Mimeo. Report No. 143, 1954; Hopkin, John A., "Economies of Size in the Cattle-Feeding Industry of California," Journal of Farm Economics, vol. 40, no. 2, May, 1958, pp. 417-429; Hedges, Trimble R., Estimated Earning of Specified Farm Types and Sizes, California Crop Farms, 1956-58 Conditions Calif. Agric. Exp. Sta. Giannini Found. Mimeo. Report No. 226, December, 1959.

only effectively, [illegible] in California agriculture. The [illegible]

[illegible]

Some basic [illegible]

Despite [illegible]

1/ See, [illegible]

the authors have initiated a series of cost-size studies focusing on different geographic areas and types of farms in California. This first study, to be released in two reports, is restricted to a specific geographic farming area--the cash crop irrigated area around Woodland in Yolo County.[1] This first report investigates farming costs associated with various combinations and levels of resources. A forthcoming second report suggests optimum adjustments in farm organization for operators shifting farm size or improving their economic position with the present size.[2]

OBJECTIVES

The major objective of this report is to examine cost economies for owned and share-rented cash crop farms in Yolo County, assuming above-average management and high efficiency in resource use. That is, cost-size relationships are approximated under ideal or optimum resource use rather than actual or "typical" conditions. The former concept more nearly depicts the relevant cost relationships for decision-making in a long-run, competitive framework.

Crop rotations vary considerably in the study area. Thus, cost relationships are examined for (1) crop rotations "typical" of those in the area and (2) optimum crop rotations with given product prices. However,

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1/ Other farming locations in California presently under study are the Yuba City-Marysville fruit area and the Imperial Valley.

2/ Dean, G. W. and H. O. Carter, Guides to Profitable Cropping Systems for Yolo County Farms. Giannini Research Report (forthcoming).

under all crop rotation assumptions, efficient production techniques and resource combinations are employed. Machinery costs are subjected to particular study because they represent a commonly cited source of cost economy.

BASIS FOR ANALYSIS OF COST ECONOMIES

The theoretical basis for analysis of cost economies is illustrated in Figure 1, using the traditional average unit cost curves of the firm.1/ The short-run average cost curves (SRAC) assume one or more resources to be fixed (a fixed "plant"), while other resources are variable; the long-run average cost curve (LRAC) assumes all resources are variable (including those designated as "fixed" in the short run). In this study, machinery is designated as the resource category fixed in the short run. Thus, $SRAC_1$ illustrates average cost per unit of output for different levels of output, assuming a fixed set of machinery, while land and other resources are variable. Curve $SRAC_2$ is a similar average cost curve based on a different fixed machinery combination composed of more and larger pieces of equipment. Curves $SRAC_3$ and $SRAC_4$ have similar interpretations for still larger fixed machinery combinations. The short-run average cost curves have a typical "u" shape: Average costs decline with an initial expansion of output as fixed costs are spread over more units, eventually, however, average costs

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1/ Concepts of economies of scale are widely discussed in economic literature. For example, see: Boulding, Kenneth E., Economic Analysis, (New York: Harper and Brothers Publishers, 1955) Third ed. p. 671-90 and Stigler, George J., The Theory of Price (New York: MacMillan Co, 1952) revised ed., p. 134-147.

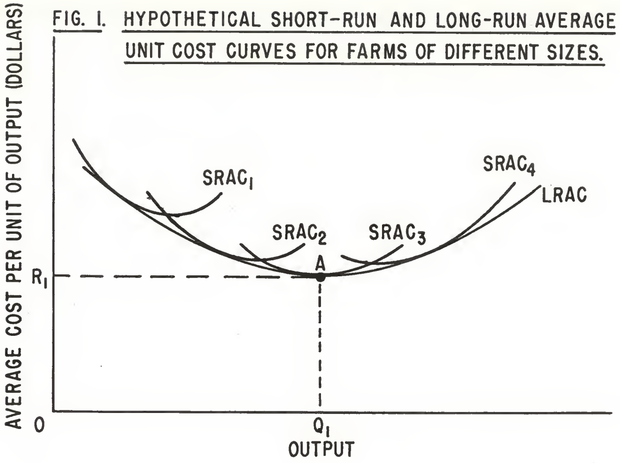

FIG. 1. HYPOTHETICAL SHORT-RUN AND LONG-RUN AVERAGE UNIT COST CURVES FOR FARMS OF DIFFERENT SIZES.

per unit of output level off and then rise as other inputs must be added in increasing proportions to the fixed machinery combination in order to reach greater output levels.

From the standpoint of trends in farm size and survival of the firm, the long-run average cost curve (LRAC) is probably most relevant. The LRAC curve is an "envelope" formed as a tangency to the short-run cost curves. Thus, the LRAC theoretically represents the minimum cost for producing each quantity of output; in this sense, the LRAC curve can be considered as a planning curve.[1/] In long range planning, a farmer with sufficient funds could select any output point on the LRAC curve. Corresponding to this point is a particular machinery combination and levels of other inputs. Once this machinery set-up has been selected, however, the LRAC is no longer relevant; the farmer is then restricted to the short-run cost curve corresponding to the machinery combination selected. Figure 1 shows that $SRAC_3$ represents the optimum machinery combination if minimum average cost is used as the criterion. In a situation forcing returns per unit of output to R_1, only farms using the optimum machinery combination (corresponding to $SRAC_3$) and operating at output Q_1 on $SRAC_3$ could survive in the long run (in a perfectly competitive economy); all other farms would have higher costs and would therefore be operating at losses. However, if average returns per unit are greater than R_1, firms with machinery combinations both larger and smaller than the "optimum" might still operate with profits.

[1/] The LRAC is only an approximation to a "practical" planning curve because machinery (and possibly other inputs) are not perfectly divisable.

The short-run and long-run cost curves of Figure 1 correspond to the classical "textbook" relationships. Alternative hypotheses are possible regarding the shapes of empirical cost curves within the relevant range of output. The "u" shape is probably quite appropriate for the short-run curves where some factor is held fixed. However, there is some question whether the LRAC curve is "u" shaped. Some argue that, because all factors (including management) are variable in the long run, the LRAC may approach a constant and never rise. Others argue that increased size brings lack of communication and other forms of "red tape," causing the LRAC curve eventually to rise. Obviously, the shapes of these curves have important bearing on trends in farm size. If the "u" shape is appropriate for the LRAC, firms would tend to limit expansion much beyond the minimum point Q_1 (unless returns were considerably above R_1, making larger output profitable). However, if LRAC declines throughout or becomes constant beyond some point, what would prevent farms from expanding size indefinitely? Perhaps the most important factor is the risk and uncertainty inherent in farming. Expansion in size ordinarily requires borrowed capital; as more borrowed capital is employed the risk of losing equity accumulated over time increases. Thus, farmers who have achieved an efficient sized unit and satisfactory incomes tend to "play it safe" in order to protect their current position. High income taxes for large farmers also may reduce the incentive to expand farm size.

Cost Economies with Varying Product Mix

The above discussion of cost economies assumes that "output" is a homogeneous product or at least a homogeneous mix of products (e.g., 1/4 sugar beets, 1/4 alfalfa, 1/4 tomatoes and 1/4 barley). In the Yolo County study

area, however, institutional and economic factors cause this "mix" of products to vary, often substantially, as farm size is expanded. Suppose an operator farms 360 acres: A feasible crop program may be 90 acres of alfalfa, 54 acres of barley, 54 acres of milo, 72 acres of sugar beets and 90 acres of tomatoes. If the operator expands his acreage three-fold to 1,080 acres, the acreages of sugar beets and tomatoes will probably expand less than proportionately. Farm survey data in the study area indicate a definite percentage trend away from the higher value, labor-intensive crops as farm size increases. Reasons are: (1) sugar beet acreage is controlled by government allotments made on the basis of historical acreage; (2) tomatoes require a contract with the canner; (3) high risk is attached to tomatoes relative to other crops; (4) expansion in acreage often necessitates leasing poorer quality soils which in turn restrict acreage on high-value crops; and (5) expansion is often encouraged by the need to utilize excess machine capacity thus making the highly-mechanized crops (e.g., barley, milo, and safflower) more feasible. These factors cause the crop mix to be nonhomogeneous as size increases.

The importance of a changing product mix for Yolo County farms expanding in size suggests that the theory for single product firms (see Figure 1 and related discussion) must be expanded to handle the more realistic situation of multiple products. With multiple products, a total cost "envelope" surface can be visualized representing the minimum cost of producing all levels of combinations of products. Conceptually this

relationship permits examination of changes in total costs as output is expanded along any trace or "path" on the n-dimensional multiple product cost surface. While such a surface might be approximated empirically,[1] the procedure would be quite costly and cumbersome with a large number of products (e.g., 5-10 crops). Further, large areas of such a surface would be irrelevant because of acreage allotments, contractual arrangements, diseases and rotational restrictions.

A relatively simple alternative procedure is used in this study: Cost relationships are derived for only a few selected relevant traces on the multiple product surface. This procedure is illustrated with a simplified two-product cost surface in Figure 2. Lines I-I', II-II', III-III' and IV-IV' in Figure 2 refer to production possibility or iso-cost curves on the total cost "envelope" surface. Empirically, the production possibility curves are formed from linear resource restrictions for fixed plants or farms of different sizes.[2] Later analyses for three separate multiple product mix situations--distinguished as Budget I, Budget II and Linear Programming--are analogous to the three "traces" illustrated for the two-product case in Figure 2. Budget I (corresponding to trace OA, Figure 2) assumes the same "average" cropping system (fixed multiple product mix) over the entire output range. Budget II (corresponding to trace OB, Figure 2) assumes a series of changing

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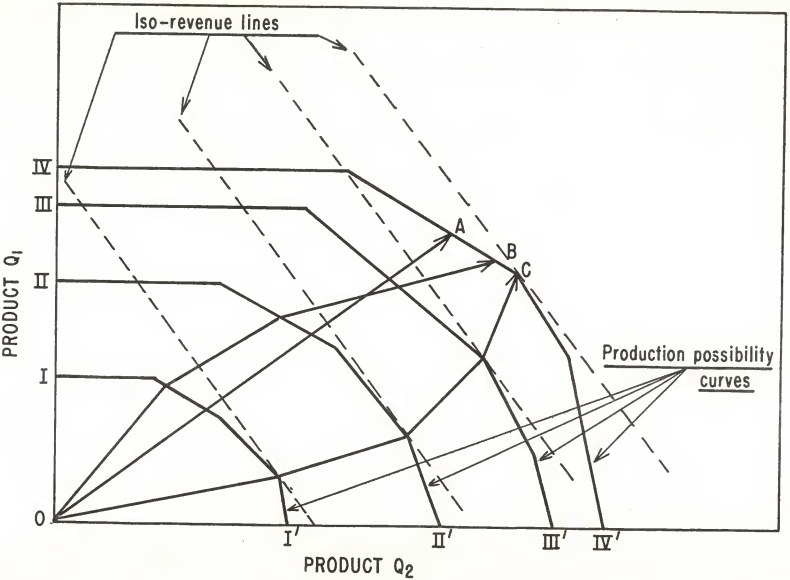
[1] For example, see: French, B. C., L. L. Sammet, and R. G. Bressler "Economic Efficiency in Plant Operations with Special Reference to the Marketing of California Pears." Hilgardia, vol. 24, no. 19, July, 1956, p. 543-721.

[2] Algebraic and graphic derivation of such production possibility curves is frequently presented in linear programming literature. For example, see: Heady, E. O. and Wilfred Candler. Linear Programming Methods. Chapter 2. (Ames: Iowa State College Press, 1958.)

FIG. 2. ALTERNATIVE PRODUCT COMBINATION "TRACES" ON A HYPOTHETICAL TOTAL COST SURFACE.



cropping systems (product mixes) "typical" of farms of different sizes. The Linear Programming situation (corresponding to trace OC, Figure 2) allows the cropping system (product mix) to change in optimum fashion as output expands. This situation is of particular interest because, given product prices, it specifies optimum expansion possibilities, consistent with the institutional and economic realities facing farmers.

Measuring Output for Multiple Product Farms

It is necessary to study cost economies along the particular traces (product mixes) of interest and also useful to compare cost economies among the various traces. However, the multiple product situations present the problem of finding an appropriate measure of output, particularly when the product mix changes (is nonhomogeneous) as output expands. Without a measure of output, no meaningful average total cost surface exists, either conceptually or empirically. In this study product prices (P_i) are specified as product (Q_i) weights; thus, total revenue ($\sum_i P_i Q_i = TR$) becomes the index of output and average cost is expressed as total cost per dollar of total revenue ($TC \div TR = ATC$). While any weighting system admittedly is somewhat arbitrary, a precedent for this procedure is found in determining total costs by weighting optimum input combinations by factor prices. Given total revenue (TR) as a measure of output, comparisons can be made of ATC ($TC \div TR$) for any conceivable trace on the total cost surface.

The critical factors in interpretation of the long run average total cost curve are the "breakeven" point ($TC = TR$ or $ATC = AR$) and the minimum ATC point. Ordinarily, this cost curve is independent of product price. How

does inclusion of product price in the output measure affect the nature of the average cost curve? In the case of a single product or multiple products in fixed proportions, use of TR as a measure of output does not affect the critical "breakeven" or "minimum" points, assuming constant product prices. That is, by transforming output into TR, the minimum point on the ATC (TC ÷ TR) curve occurs at the same product combination and level as the minimum total cost per unit of the physical product or fixed product combination. Neither do changes in the product price level (relative product prices constant) affect the product level and combination corresponding to the minimum point on the ATC (TC ÷ TR) curve. (Of course, with changes in the product price level, the minimum ATC occurs at a different TR, but still corresponds to the same physical product quantities.) Also, in the more complex case where multiple products expand in nonconstant proportions,, it can be shown that changes in the price level (relative product prices constant) do not change the physical product combination and level corresponding to the minimum point on the ATC (TC ÷ TR) curves. Thus, if relative product prices are assumed constant with changes only in the price level, use of TR as a measure of output does not distort the cost economies relationships.

In the following empirical sections, individual cost curves and comparisons are expressed in terms of ATC (TC ÷ TR) in relation to output (TR). However, while TR can be defended as a conceptually useful measure of output, farmers conventionally think of farm size in terms of acres operated or investment in land and machinery. Hence, later empirical results are also related to these common size indicators.

SOURCES OF DATA

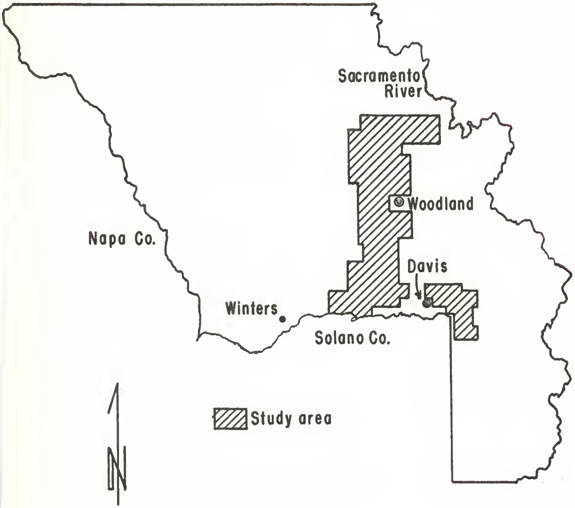
Data for the study came primarily from personal interviews with a sample of farmers taken during the summer of 1959. These data were supplemented with engineering and cost data from secondary sources, primarily publications of the California Agricultural Extension Service.

The sample was drawn from the 96 square-mile area of Yolo County outlined in Figure 3. This area was defined primarily on the basis of including the main body of soils in the Yolo series, which, in turn, restricted the type-of-farming to relative homogeniety. Most farm land in the area has been developed for irrigation, with water coming primarily from underground pumping.

A statistical area probability sample[1/] was drawn as follows: The area was divided into four strata of 24 square-mile sections each. A proportionate sample of four square-mile sections was drawn at random from each stratum and every "eligible" farmer whose headquarters was located in the selected sections was contracted and interviewed. After making the initial contacts however, it became apparent that the average number of "eligible" farmers per section would be considerably less than anticipated. A few extremely large farms operating in the area resulted in drawing certain sections with no headquarters. To avoid bias and to increase the sample size sufficiently, nearly a complete enumeration of "eligible" farmers in the area was necessary.

[1/] For further discussion of area probability sampling see: Houseman, Earl E., Application of Probability Area Sampling to Farm Surveys (Washington: Govt. Print. Off., May, 1954) (U. S. Department of Agriculture Handbook No. 67.)

FIG. 3. THE STUDY AREA OF YOLO COUNTY.



"Eligible" farms in each mile section were those meeting the three following criteria:

1. Location of headquarters. The headquarters for the ranch or farm must be located within the sample section. The headquarters was considered to be the main machinery repair center for the operation. Use of the machinery repair center rather than the usual "farmstead" as the headquarters criterion was necessary because many farmers live in Woodland, Yolo, Davis or other towns near the sample area and do not maintain a "farmstead" in the usual sense. Yet every farm has a main machinery repair center, which in most cases also includes machinery storage facilities, ranch foreman's home or other buildings at the site.

2. Commercial farming. The farm must be a "commercial" farm. The purpose of this criterion was to eliminate small, part-time farming operations or farms not operated primarily for profit (e.g., a "hobby" farm, experimental farm, etc.). An average annual gross income in excess of $5,000 was required for "eligibility."

3. Type of farming. At least eighty percent of the farm gross income must be from cash crop farming. In other words, farms with orchards, speciality vegetable crops (other than tomatoes), or livestock operations (dairies feed lots, etc.) producing individually or collectively more than 20 percent of the gross income were excluded from the sample.

Records for the 1958 crop year were obtained from each of the farms interviewed. Information on land, labor use, crop acreages, yields, production, machinery and equipment investment, farm expenses and income were obtained. In most cases, the figures were given directly from income tax

records and other farm records. In a few cases, figures were obtained largely from memory with the help of fragmentary records. Thus, memory bias may be a problem in some of the schedules.

In all, interview schedules from 58 farmers in the area were obtained. Of these, 37 schedules were used in the analysis. Of the 19 schedules not used, 8 were specialized tomato growers (these may be analyzed separately at a later date), 7 were farms specializing in either all grain crops or all alfalfa and 6 were not used on the basis of inaccurate or incomplete information. The rate of "refusals" and "unable to contact" was reasonably low, totaling about 10 percent.

Characteristics of the Sampled Farms

Table 3 summarizes the mean and range of some of the main characteristics of the 37-farm sample. All data refer to operations for the 1958 calendar year. Nearly three-fourths of the total land acreage was rented; many of the large individual operations in the area were wholly or dominatly tenant operations. Furthermore, the individual tracts of leased property were often widely separated--by 15-20 miles in some cases. Only about 5 percent of the cropland on the 37 farms was nonirrigable; most farms were completely developed for irrigation.

The crop production summary (Table 3) provides relative acreages of each crop; these acreages are considered later in developing typical crop rotations for purposes of budgeting cost curves. Because 1958 was a somewhat unfavorable crop year (due primarily to late spring rains which delayed field operations), both 1958 "actual" yields and estimated "normal" yields

TABLE 3

Characteristics of the Sample of Farms, 1958[a]

Item	Unit	Mean	Range	
			Low	High
Land:				
Total land	acres	842	71	4,000
Land owned	acres	236	0	1,240
Land rented	acres	606	0	3,560
Irrigable cropland[b]	acres	776	65	4,000
Nonirrigable cropland[c]	acres	45	0	534
Wasteland	acres	21	0	160
Crop production:[d]				
Sugar beets--acreage	acres	99	0	310
1958 yield	tons/acre	17	7.5	27.7
"normal" yield	tons/acre	22	15	27
Tomatoes--acreage	acres	164	0	648
1958 yield	tons/acre	20	5	31
"normal" yield	tons/acre	22	17	30
Barley--acreage	acres	186	0	1,300
1958 yield	cwt/acre	26	14	40
"normal" yield	cwt/acre	31	20	40
Alfalfa--acreage	acres	116	0	780
1958 yield	tons/acre	6	3	9
"normal" yield	tons/acre	7	4	10.4
Milo--acreage	acres	71	0	700
1958 yield	cwt/acre	37	10	72
"normal" yield	cwt/acre	43	11	60
Other crops--acreage	acres	177	0	1,005
Labor:				
Total labor	$/year	48,536	5,400	212,733
Hired labor	$/year	38,293	992	198,333
Supervisory labor[e]	$/year	10,243	3,600	31,200
Machinery investment (mkt.value)	$	37,241	4,100	109,775
Productive cash expenses[f]	$/year	33,483	2,399	127,791
Gross income:[g]				
1958 prices, 1958 yields	$/year	124,348	7,471	397,957
1958 prices, "normal" yields	$/year	148,676	8,578	456,933
"normal" prices, "normal" yields	$/year	146,896	8,415	450,757

(Continued on next page.)

(Table 3 continued.)

a/ Based on records from a sample of 37 farms in Yolo County.

b/ Developed for irrigation, even if not actually irrigated in 1958.

c/ Not developed for irrigation.

d/ Acres of individual crops do not necessarily add to total cropland since some land is double cropped. "Normal" yields were estimated as the estimated average yield over the previous five years.

e/ Includes hired foreman as well as operator labor.

f/ Includes only cash expenses directly related to output.

g/ "Normal" prices are defined as the average price over the previous five years.

were obtained from each farmer.[1] For every crop, "normal" yields averaged higher than 1958 actual yields, although some bias may be encountered in farmers' varying interpretation and memory of "normality." All inputs and gross income were adjusted to reflect "normal" yields for the major part of the analysis, in order to more nearly represent typical conditions than actual 1958 data.

The average labor input per farm (Table 3) was nearly $50,000, reflecting substantial acreages of labor-intensive tomatoes and sugar beets as well as the large farm sizes in the area. About 80 percent of this labor was hired (seasonal and year-round) and about 20 percent was supervisory (including hired foreman and operator). Average machinery investment (at market value) and productive cash expenses per farm of $37,241 and $33,483 further illustrate the highly commercialized operations studied.

EMPIRICAL ANALYSIS OF COST RELATIONSHIPS

The analysis was devised to obtain estimates of selected short-run average cost curves as well as the "envelope" curve or long-run average cost curve (see Figures 1 and 2 and related discussion). Therefore, the farms in the 37 farm sample were first divided into four size classes in terms of acreage: 160-320 acres, 320-640 acres, 640-1200 acres and over 1200 acres. From the survey information on these farms, four machinery and equipment lists (I, II, III, IV) were developed, representing "typical" machinery combinations for farms in each of the four acreage categories (Table 4). This "typical" machinery and equipment then constituted the

---

[1] "Normal" yields were defined as the estimated average yield over the previous five-year period.

TABLE 4

Typical Machinery Combinations for Farms of Various Size, Yolo County, 1958[a]

Type of machine	Machinery combination for farm sizes			
	I (160-320 ac.)	II (320-640 ac.)	III (640-1200 ac.)	IV (1200 ac. and more)
	No. of each type of machine			
utomotive equipment:				
Pickups	2	2	3	4
Trucks-flatbeds	1	1	2	3
Trailers-highway	1	1	2	3
Trailers-lowbed	1	1	1	1
Implement carryalls	1	1	1	2
ower equipment:				
Crawler tractors 40 CDBHP	1	0	1	1
50 "	0	1	0	0
60 "	1	1	2	2
100 "	0	0	0	1
Wheel tractors 20 "	2	1	2	4
30 "	0	1	1	2
and preparation equipment:				
Chisels	1	1	2	3
Harrows-spike	1-12'	1-18'	2-20'	2-30'
Harrows-spring	1-12'	1-18'	2-20'	2-30'
Harrow cart	0	1	1	3
Roller	1-12'	1-18'	1-20'	1-25'
Tool bar	1	1	1	3
By hoe	0	0	1	1
Ditcher	1	1	1	1
Disk: up to 8'	1	0	0	0
8-14'	1	2	1	3
14'	0	0	1	3
Plow: 1-2 bottom	0	0	0	1
3-5 "	1	1	1	3
lanting and cultivating equip:				
Tomato planter	0	0	2	2
Seeder	1	1	1	2
Drill	1	1	1	1
Cultivator	2	2	3	3
Beet thinner	0	0	1	1
Sprayer	1-200 gal.	1-400 gal.	1-500 gal.	1-600 gal.
Duster	0	0	0	1
Ridger	0	0	1	1
Lister	0	1	1	1
arvesting equipment:				
Beet digger - 1 row	0	1	0	1
Beet digger - 2 row	0	0	1	1
Combine (self-propel)	1-12'	1-12'	1-16'	2-16'
Mower	1-6'	1-8'	2-6'	2-8'
Baler	0	0	0	1
Rake	2	2	2	3
Bale loader	0	0	0	1
Beet topper	0	0	1	1
and leveling equipment:				
Land plane	0	1	1	2
Drag or float	0	1	1	1

a/ Source: Sample of 37 cash crop farms; Yolo County.

"fixed" resource assumed in deriving four short-run average cost curves--land, labor, and other inputs were considered variable. The short-run average cost curves were terminated by the "capacity" (later defined) of each machinery combination, not by an arbitrary acreage limit. A long-run average cost curve (or planning curve) was then approximated as an envelope to the four short-run average cost curves.[1]

Presentation of the empirical results is divided into two major sections--the first dealing with operator cost relationships on owned farms, the second with operator costs on share-rented farms. Within each of these tenure situations a distinction is maintained between Budget I and Budget II. Budget I assumes a common cropping system for all acreages (corresponding to trace OA, Figure 2). Budget II assumes a different cropping system for each of the four size groups defined above (corresponding to trace OB, Figure 2). For the rented situation, a Linear Programming analysis derives a cropping system which minimizes cost for all output (total revenue) levels (corresponding to trace OC, Figure 2).

Tables 5 and 6 summarize the rotation data assumed for Budgets I and II, respectively. In all of the analyses, constant yields per acre and constant prices are assumed for all farm sizes.[2] The per acre gross income or total revenue (TR) data of Tables 5 and 6 allow a ready conversion of the later empirical measures of output (farm gross income or TR) into the more common measure of acres per farm.

1/ It is recognized that the machinery combinations selected are "typical" rather than "optimum" for each farm size. Thus, the envelope to the short-run cost curves is only an approximation to the long-run average cost curve.

2/ Survey data indicated that yields per acre were not greatly different among size groups, and no trend with size was apparent. There also was little evidence to support a hypothesis of different product prices received on farms of different sizes.

[illegible]

[illegible]

[illegible]

[illegible]

TABLE 5

Rotation Data Assumed in Budget I

Crop	Unit	Yield per acre[a]	Price per unit[b]	Gross income per acre	Percent of acreage in rotation[c]	Owner-operator's gross income per acre of rotation	Share renter's gross income per acre of rotation[d]
			dollars		percent	dollars	
Alfalfa	tons	7.3	22.00	160.60	25	40.15	30.11
Barley	cwt.	31.2	2.00	62.40	15	9.36	5.62
Milo	cwt.	43.0	2.10	90.30	15	13.54	10.16
Sugar beets	tons	21.6	13.00	280.80	20	56.16	44.93
Tomatoes	tons	22.5	22.00	495.00	25	123.75	105.19
All crops	--	--	--	--	100	242.96	196.01

a/ Average of "normal" yields per acre from sample (see Table 3).

b/ For a complete list of price assumptions used for all crops considered in the analysis (see Appendix, Table A-2).

c/ Overall averages based on sample of farms and adjusted to reflect a feasible individual farm rotation.

d/ Share-renter's gross income based on the typical share leasing arrangements in Yolo County (see Appendix Table A-1).

TABLE 6

Rotation Data Assumed in Budget II

Crop	Percentage of acreage in rotation by size groups[a]				Owner's gross income per acre of rotation[b]				Share-renter's gross income per acre of rotation[c]			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
	percent				dollars				dollars			
Alfalfa	15	20	25	30	24.09	32.12	40.15	48.18	18.07	24.09	30.11	36.14
Barley	10	20	20	25	6.24	12.48	12.48	15.60	3.74	7.49	7.49	9.36
Milo	15	15	20	20	13.54	13.54	18.06	18.06	10.16	10.16	13.54	13.54
Sugar beets	20	15	15	10	56.16	42.12	42.12	28.08	44.93	33.70	33.70	22.46
Tomatoes	40	30	20	15	198.00	148.50	99.00	74.25	168.30	126.22	84.15	63.11
All crops	100	100	100	100	298.03	248.76	211.81	184.17	245.20	201.66	168.99	144.61

[a] Rotations for different size groups based on farm sample information and adjusted to reflect a feasible individual farm cropping system.

[b] See Table 5 for assumptions regarding prices and yields.

[c] See Appendix Table A-1 for typical leasing arrangements assumed.

Cost Structures for Owner-Operated Farms

Cost Curves for Machinery (Budget I)

Economy in the ownership and operation of farm machinery is often cited as the major cost advantage associated with increased size. Therefore, machinery costs first are analyzed separately, then incorporated with other costs to obtain total per acre cost curves.. Also, for this analysis, power machinery (tracklayer and wheel tractors) is defined as the major resource which limits short run (say, one year) expansion in farm size. Although custom operators are generally available to perform the major harvesting tasks (baling, combining and sugar beet digging) organized custom operators are not readily available to perform the usual field operations involving heavy tillage, planting and cultivating. Accordingly, tracklayer power and wheel tractor power available by time periods were determined (see Table A-4). Daily rainfall data for the past 15 years in the Woodland area were used to estimate the average number of days per month available for field operations; then, assuming a 10-hour day, tractor hours available monthly for field operations were determined. From these calculations estimates of the maximum number of acres of a specified rotation that can be operated were obtained for each machinery combination.[1]

Figure 4 shows machinery costs per acre (for the rotation specified in Table 5) for a range of acreages for each of the four "fixed" machinery

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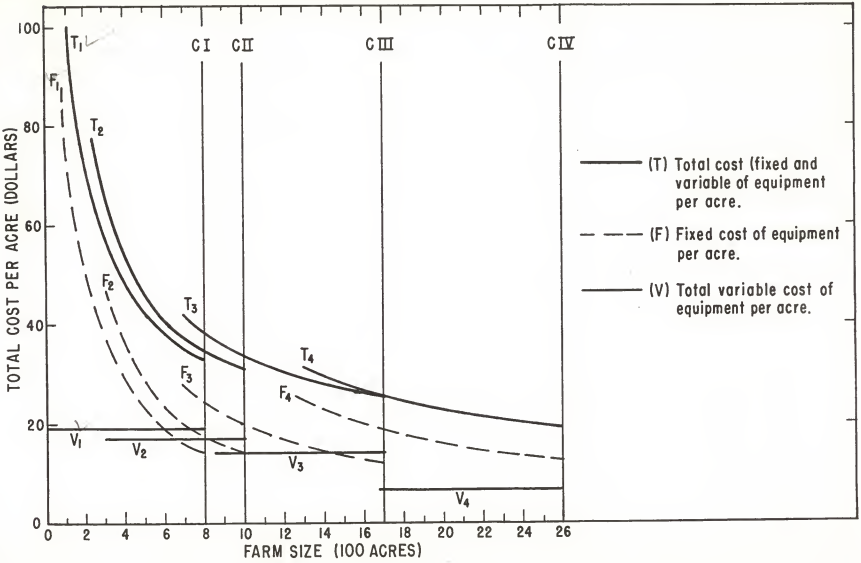
[1] One limitation apparent in this procedure is that some farmers operate tractors in "busy" periods more than 10 hours per day.

FIG. 4. MACHINERY AND EQUIPMENT COSTS PER ACRE FOUR MACHINERY COMBINATIONS (I, II, III AND IV) USED AT DIFFERENT ACREAGE LEVELS.



T/A

A

combinations.[1] Each cost curve is extended to an acreage limit corresponding to full capacity use of the power equipment (defined above) as designated by vertical lines C_I, C_{II}, C_{III} and C_{IV}. For example, curve T_1 represents total machinery costs per acre of operating from 160 to 711 acres with machinery combination I. Curves F_1 and V_1 represent the fixed and variable cost components, respectively, of total costs T_1. Other cost curves in Figure 4 have a similar interpretation for machinery combinations II, III, and IV. Fixed costs for machinery include annual depreciation, 7 percent interest on the average investment, insurance, and the "fixed" component of machinery repairs.[2] Variable costs of machinery operation include fuel, oil, lubrication, tires, and the "variable" components of machinery repairs. Custom work, where required, was also charged as a variable machinery cost. For example, farmers with machinery typical of the 160-320 acre range have no beet digger (machinery combination I, Table 4). Therefore, custom beet digging costs enter variable costs (V_1) for this size range. Labor costs are not included in variable machinery costs[3] but are included later in presentation of total per acre cost curves.

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[1] Machinery costs for budgeting purposes were obtained primarily from: Sample Costs of Production; Equipment Charges and Cost Estimates of Selected Crops, Woodland Area, Yolo County, 1958, (Woodland: Calif. Agr. Ext. Serv., 1958). Reed, A. D., Machinery Costs and Related Data, (Davis: Calif. Agr. Ext. Serv, 1959). Reed, A. D., Custom Rates for Farm Operations, (Davis, Calif. Agr. Ext. Serv., 1957). These sources are supplemented by other miscellaneous publications and by inquiries of machinery dealers.

[2] Machinery repairs are divided into two components: (1) A "fixed" portion required to maintain the equipment with minimum use and (2) a "variable" portion assumed to increase proportionately with use above the minimum level.

[3] Except for custom work, where labor costs are inseparable from other components of the custom rate.

Figure 4 indicates that per acre machinery fixed costs drop substantially as they are "spread" over greater acreages, particularly for equipment in the 160-320 acre range. Machinery variable costs per acre are constant within each size group but are successively lower for each larger size group, reflecting per acre reductions in fuel and oil consumption as larger capacity machinery is used.[1] Part of the drop in variable costs per acre between size groups is also attributable to a gradual shift from contracting to ownership of high-cost machinery for specialized operations. For example, hay baling is shifted from a contract to owner operation between size group III and IV, thereby shifting baling costs from the variable to fixed category. The total per acre machinery cost curves of Figure 4 (fixed costs plus variable costs) decline fairly smoothly over the entire size range. The discontinuities between size groups indicate the machinery costs are reduced by operating smaller machinery to capacity versus under-utilizing larger machinery. However, when used to capacity, each larger machinery combination has a per acre machinery cost advantage over the next smaller combination.

In Figure 5 a long-run per acre machinery cost curve is drawn as an "envelope" to the short-run curves.[1] The "envelope" shows minimum machinery costs per acre associated with the entire acreage range from 100 to 2,600 acres. Machinery costs per acre decline sharply at lower acreages and continue

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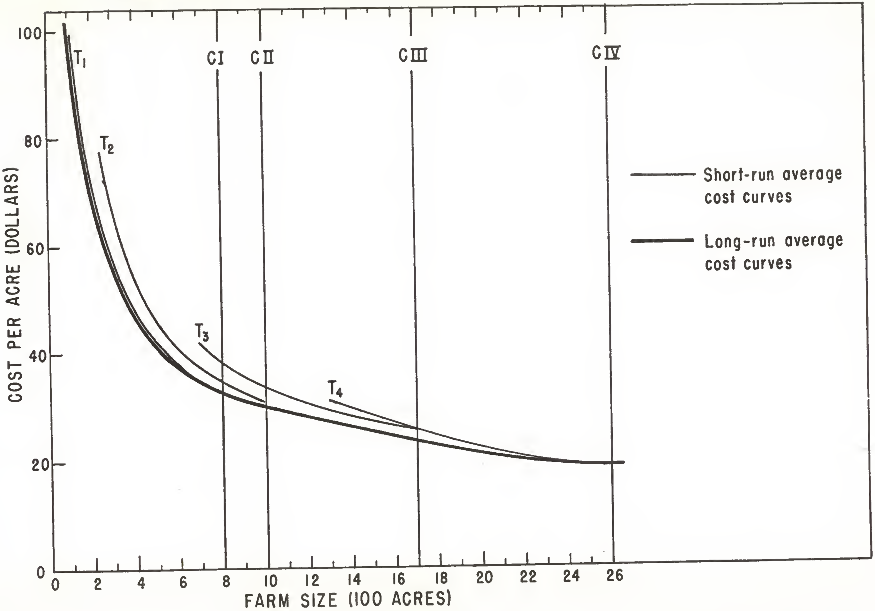
1/ No difference in price paid for fuel, repairs and related inputs was assumed for different size groups.

2/ Conceptually, an infinite number of short-run cost curves relating to successively larger machinery combinations are required to draw an "envelope" curve. The long-run cost curve of Figure 5 is only an empirical approximation to the "envelope" curve.

FIG. 5. MACHINERY AND EQUIPMENT COSTS PER ACRE FOR FOUR MACHINERY COMBINATIONS AND LONG-RUN AVERAGE COST CURVE.



to decline over the entire range. Beyond 600-700 acres average costs decline nearly linearly at the rate of approximately $1 per acre for each additional 100 acres operated. These results indicate not only cost economies in capacity use of given machinery, but cost economies in shifting to larger and larger capacity machinery.

In the low acreage range in Figure 5, the envelope curve is based on a considerable amount of machinery custom work. Thus, with machinery combination I, hay baling, sugar beet digging, and certain other operations are assumed to be contracted (see Table 4). At extremely small acreages, however, there are several other possibilities which might reduce machinery costs below those shown in Figure 5: (1) Most or all of the remaining field operations might be hired on a custom basis. (This possibility has limited application on a wide scale because of lack of custom operators for ordinary tillage operation.) (2) The small operator might own expensive equipment but reduce the cost per unit by doing custom work for others. (3) Machinery might be owned in partnership with a neighbor or the neighbors might each own different pieces of specialized equipment and exchange machinery services. (4) The operators might reduce costs by using second-hand equipment. Incorporation of these alternatives in the analysis might have lowered the envelope curve somewhat for very small acreages, but would have had neglible influence on costs over the more relevant acreage range.

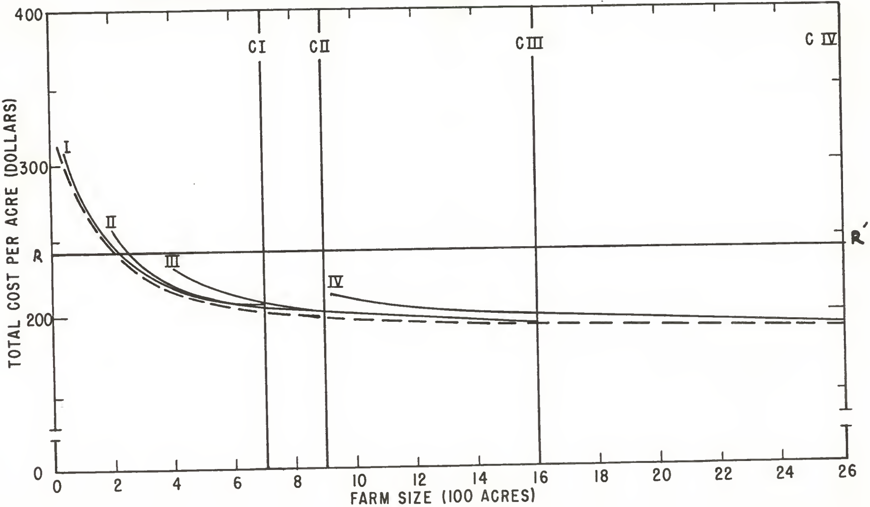
Cost Curves for all Inputs (Budget I)

Machinery costs are now incorporated with all other costs to arrive at total costs per acre of rotation for farms of different sizes. Aside from machinery, labor costs represent the largest single cost item. Labor

costs include machinery operation (including moving and servicing equipment) at $1.25 per hour, irrigation and seasonal labor for hoeing sugar beets at $1.00 per hour and tomato picking at 12 cents, 13 cents, and 15 cents per box for the fist, second, and third pickings, respectively. It was assumed that larger farmers had their own labor camp facilities for seasonal labor and that smaller farmers had access to workers from cooperative camps at comparable costs. Therefore, labor costs also included camp charges, crew supervision, transportation for workers and other costs related to seasonal labor. Compensation insurance and social security taxes were included for all domestic laborers. For all acreages, labor costs were $70-72 per acre. Reduction in labor cost through use of larger equipment was approximately offset by the shift to less custom work and more owner operations as farm size increased. However, if a smaller farmer did not have access to a cooperative labor camp as assumed, labor costs per acre for that group would be higher. Also included in the total per acre costs are seed, fertilizer, sprays, dusts, electricity (primarily for irrigation), interest on the land investment of $48 per acre ($800 land @ 6 percent), land taxes of $8 per acre, and miscellaneous costs such as grower association dues, phone, and roadside weed control. In summary, an attempt was made to incorporate all costs, including a market rate of return on capital investment.

Figure 6 summarizes the total costs per acre of rotation for farms of different acreages. Again, curves I, II, III and IV refer to short-run average cost curves for the corresponding machinery combinations. Curve PC I is a planning curve drawn as an "envelope" to the short-run curves. As with machinery costs alone, the average total cost per acre of rotation declines sharply to about 600-700 acres, then declines slowly throughout.

FIG. 6. AVERAGE TOTAL COST CURVES (ALL INPUTS) FOR FOUR FARM MACHINERY COMBINATIONS AND ENVELOPE OR PLANNING CURVE. (BUDGET I).



Line RR' at $242.96 per acre represents the average gross income (average revenue) per acre from the selected rotation, based on normal yields and expected prices (refer to Table 5). Thus, farmers with less than about 200 acres would be operating at a loss (average total cost greater than average revenue), or accepting lower returns on their resources than could be obtained elsewhere. Yet some farmers in this category continue to operate because (1) they are willing to sacrifice monetary returns (in terms of what could be earned elsewhere) for the opportunity of "living in the country" or other nonmonetary considerations, and/or (2) they are "living off" the machinery depreciation (i.e., not setting aside funds for replacement of depleted machinery). In the first case, the operators may stay in farming indefinitely, accepting minimum monetary returns; in the second, they can remain in farming only for the "short run." Farms over 200 acres obtain increasingly greater profit per acre as size is increased within the range considered. However, operations of 600-700 acres compete closely with larger farms on a per unit cost and profit basis. Of course, total profit continues to increase beyond this point, but mainly through greater business volume rather than through greater unit profits.

Cost Curves for All Inputs (Budget II)

The Budget I analysis assumed a constant rotation for all farm sizes. For reasons emphasized earlier, however, actual cropping patterns in the area shift toward proportionately more of the lower value crops (e.g., barley and milo) as acreage expands. Because of this "shift," the Budget I assumption of a homogeneous "product mix" (fixed cropping system for all acreages) is now relaxed to allow different cropping systems "typical" of each of the four size groups (see data in Table 6).

Curves I, II, III, and IV (Figure 7) represent short-run average cost curves for the corresponding machinery combinations and cropping systems.[1] Curve PC II, drawn as an envelope to the short-run curves, declines sharply, then flattens out at an output level of about $150,000 (approximately 500-600 acres). Under these cost relationships (Budget II), farms of less than about 160 acres would be operating at a loss (average cost greater than average return) compared to a "break-even" point of 200 acres (Budget I). This difference results from a more intensive cropping system for Size I farms under Budget II than under Budget I (compare percentages of land in each crop in Tables 5 and 6). Farms with acreage in excess of 160 acres realize increasingly greater profits per dollar of output (TR) up to the level of about $150,000. Farms beyond this output organized in the manner described appear to have little or no advantage on a cost per unit of output basis.

It is emphasized that the cost and revenue functions of Figures 6 and 7 are based on above-average farming efficiency, normal yields, and normal prices. Figure 7 (Budget II) is perhaps closer to existing conditions than Figure 6 (Budget I) because the cropping systems in Budget II correspond more closely to those typically found in the respective size groups. Again, no economies are assumed in buying resources or in marketing products in quantity; likewise, no diseconomies of inefficient labor use or "red tape" are assumed as size increases. In summary, the Budget II analysis suggests that "smaller" farms can and apparently do offset part of the cost economies of machine operation on large acreages by farming more intensively (i.e., employing higher-value cropping systems). Stated conversely, farms without

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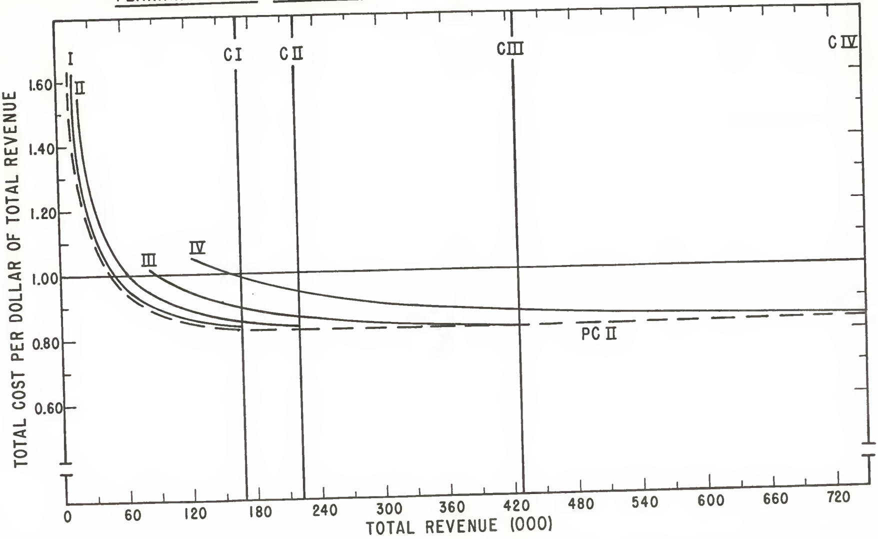
[1] For Budget II total costs per dollar of total revenue are plotted against total revenue. As discussed previously this provides a more meaningful comparison of cost structures for different sized operations when the cropping system is different for each size group.

FIG. 7. AVERAGE TOTAL COST CURVES FOR FOUR MACHINERY COMBINATIONS AND ENVELOPE OR PLANNING CURVE. (BUDGET II).



the benefit of large tomato contracts or government allotments for sugar beets must operate at substantially larger acreages to achieve the same profit margin as the smaller operator with these benefits.

Comparison of Budget I and Budget II with Sample Farm Observations

Figure 8 compares the planning curve from Budget I (PC I from Figure 6 when converted to average cost per dollar of total revenue), the comparable curve for Budget II (PC II from Figure 7), and the 37 sample farm observations. The two long-run cost curves are almost identical at lower levels of total revenue (up to about $150,000 total revenue), beyond which PC I continues a slight decline while PC II levels out. The divergent shapes of PC I and PC II are directly related to the basic assumptions underlying each. For PC I, the cropping pattern is held constant throughout; hence, due to spreading of the fixed costs (primarily machinery), per unit costs decline continuously. However, for PC II, the cropping pattern shifts with each size group (Table 6) toward less intensive-lower value crops; the net result is that, after the initial major cost economies from machinery are realized (up to about $150,000 of output), subsequent minor economies are offset by the increasing proportion of lower value crops in the rotation.1/

A striking feature of Figure 8 is that the largest farm observations do not extend beyond about $350,000 of output, yet the budgeted functions show that with machinery combination IV used to capacity, output could be extended to about twice that amount. Machinery combination IV was derived

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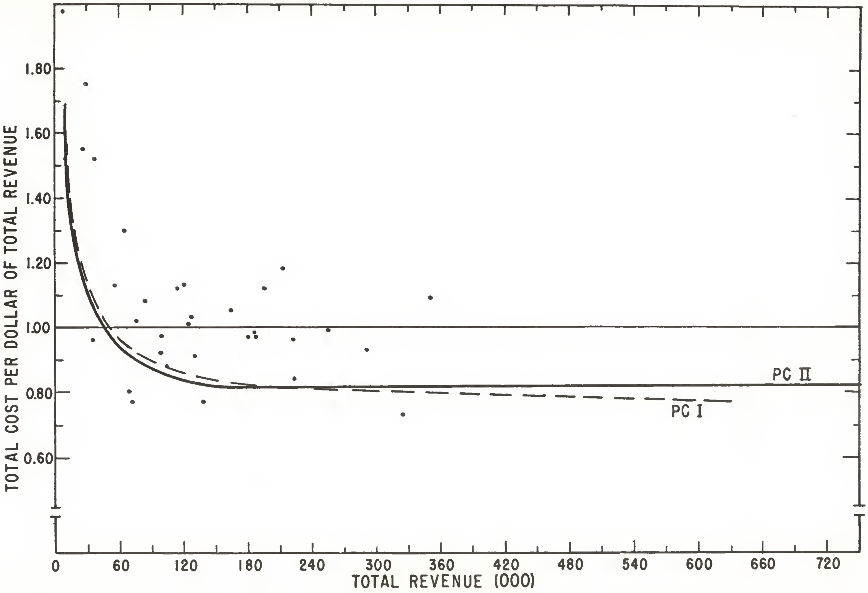
1/ The PC II curve is probably biased slightly upward at higher output (TR) levels due to the method used in computing land costs. That is, land values assumed ($800 per acre) are based on the higher quality developed Yolo soils, whereas expansion of operations toward the lower value crops generally takes place on the poorer soils or on a share rental basis.

FIG. 8. COMPARISON OF PLANNING CURVES DERIVED FOR TWO BUDGETING SITUATIONS AND SAMPLE FARM OBSERVATIONS.



directly from the largest farms, suggesting that none of the larger farms sampled are using machinery nearly to capacity. However, some "over-investment' in equipment may be rational as a hedge against losing all or part of a crop when bad weather or breakdowns limit time for field operations. This idea can be partially demonstrated by comparing the actual performance of the 37 sample farms in 1958 (a year of late spring rains hampering field operation) with their performance when adjusted for normal weather conditions. Farms normally utilizing their machinery at less than 25% capacity experienced only a 4% increase in average total costs (TC ÷ TR) in 1958 compared with a normal year; farms normally operating equipment from 25-75% of capacity experienced in 12% increase in average total costs in 1958, while those normally operating at 75-100% capacity experienced a 17% increase in average costs in 1958. While other factors (such as operating machinery more hours per day when time is limited) undoubtedly influence this comparison, indications are that firms with little excess machinery capacity generally suffer most under unfavorable weather conditions. Still, it appears that many farmers in the area have invested in equipment far beyond that required as reasonable protection against unfavorable weather.

The actual farm observations in Figure 8 also markedly indicate the extreme variability among farms in total costs per unit of output, particularly at low output levels. Farms under $80,000 of gross income revealed variations of over 100 percent in costs per dollar of gross income. Also, many farms with less than $100,000 gross income were more efficient on a per unit cost basis than farms several times larger. As pointed out earlier, actual 1958 individual farm costs and returns were adjusted to reflect normal yields and prices. Yet a substantial number (16 farmers out of 37) had unit costs exceeding returns (total costs greater than total returns).

[illegible]

[illegible] in Figure 9 [illegible]

The farm observations (adjusted for normal yields and prices), when plotted against PC I and PC II in Figure 8, show a general downward cost trend with increased size. Thus, inefficient farms were concentrated in, although not limited to, the smaller size ranges. For example, five out of six farms with output of less than $60,000 (approximately 250 acres of the "standard" Budget I rotation), had unit costs higher than unit returns (costs of over $1.00 per $1.00 of total revenue); with output (TR) of less than $140,000 (approximately 520 acres) 12 farmers out of 22 had costs greater than returns. On the other hand, with output (TR) of over $140,000 only 4 farms out of 15 had costs in excess of returns.

To repeat, costs as defined here include a market rate of return to operator and family labor and to investment in machinery and land. Since these costs do not represent an "out of pocket" cost, not all firms with costs greater than returns are involved in cash losses. However, such operators are losing in the "opportunity cost" sense that they are receiving rates of return on their labor and capital investment which are lower than they could obtain in alternative uses requiring comparable skills and involving similar risks. In fact, several of the smallest farms have insufficient returns to cover depreciation on their machinery. Unless these operators have sources of outside funds, they cannot continue in business once their machinery and equipment wears out. In the near future, these farms will probably be combined with other units to reach efficient size.

Theoretically, the budgeted planning curves of Figure 8, based on above average efficiency, should form an approximate envelope curve to the actual farm observations; this condition is approximately met in that only five farms have costs below the budgeted curves. Actual farm costs could

lie above the efficient budgeted costs for several reasons, among which are (1) non-capacity use of machinery, (2) low intensity cropping systems, and (3) inefficient management and organization of day-to-day work with resultant high costs. Less easy to explain are the five points lying below the budgeted cost curves. Examination of the five particular farms suggests the major reason for the exceptionally low cost per unit of output (TR) is a more intensive crop combination than that assumed in budgeting. While these intensive crop combinations may occur in any single year, they cannot be considered "typical" for a long-run rotation.[1/]

Assuming that the budgeted envelope curves are reasonable approximations to the "true" planning curves for owned operations in the Woodland area, these statements can be made: Given the institutional and economic constraints found in the area, owner-operations of about $150,000 (500-600 acres) are nearly as efficient in terms of per unit costs and profits as larger farms, providing the owners employ above-average techniques of production and use machinery to near capacity. However, even with constant per unit profit margins, the total return to management is still increasing rapidly enough to encourage size expansion. Risk and uncertainty is undoubtedly a significant factor limiting expansion. In the unfavorable year of 1958, for example, only 11 of the 37 farms made a profit. Other factors limiting expansion are probably (1) capital limitations and a limited rate of accumulation of equity,

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1/ Many of the 37 farm observations are actually rented operations which have been adjusted to an equivalent owned basis before plotting in Figure 8. Thus, the highly intensive rotations may result from renter operations which farm different parcels of land each year in order to plant larger acreage of the highly intensive crops.

(2) satisfaction with current incomes, reducing the incentive for even larger incomes and (3) progressive income tax rates.

Cost Structures for Rented Farms

In the sample area of Yolo County, share-renting total and partial acreages is commonly practiced. Accordingly, the following analysis presents estimates of short-run and long-run cost curves for farms operating exclusively on a share-rental basis. The basic data and procedures followed for deriving cost curves are identical to those used in the previous sections except that (1) land taxes and interest on land investment are excluded from total costs and (2) crop income is reduced to represent only the share received by the renter.[1/] Again, cost curves are obtained both for Budget I (a common cropping system for all acreages) and for Budget II (a separate cropping system "typical" of each of the four size groups). In addition, cost curves are obtained for "optimum" or profit maximizing cropping systems derived by linear programming.

Cost Curves for All Inputs (Budgets I and II)

Figures 9 and 10 show short-run average cost curves (I, II, III, and IV) with the corresponding planning curves (PC I' and II') for Budget I and Budget II, respectively. The planning curves for Budget I and Budget II follow substantially the same curvature as their counterparts for the owner operations. Both planning curves (Figures 9 and 10) tend to "flatten out" at almost the same output (TR) level (about $150,000) as for the owner

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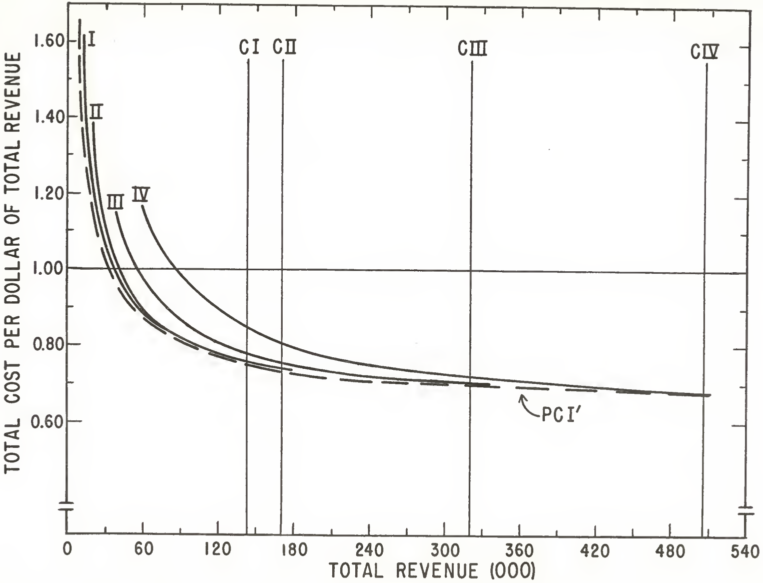
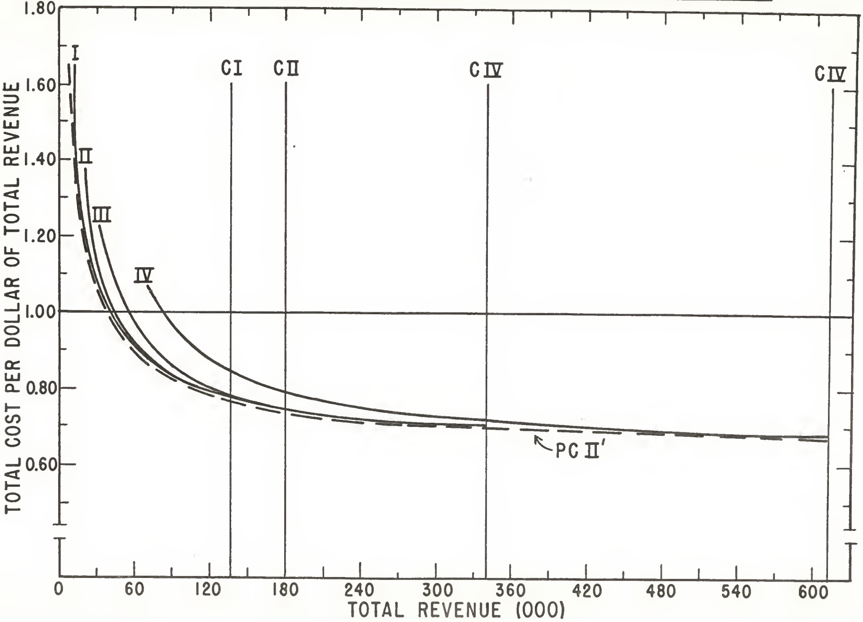
[1/] Appendix Table A-1 shows the "typical" share rental percentages used in the analysis. Tenant gross returns for cropping systems employed for Budgets I and II are given in Tables 5 and 6.

AND ENVELOPE OR PLANNING CURVE. (BUDGET I, RENTED SITUATION)



ENVELOPE OR PLANNING CURVE. (BUDGET II, RENTED SITUATION).



operations shown in Figure 8. Two major differences, however, are: (1) Comparable levels of total revenue for "share-renters" and "owners" do not imply comparable size in terms of acres operated; e.g., a total revenue of $150,000 obtained by share renting corresponds to about one-fifth more acres operated than the same income on owned land. Hence, the corresponding size at which per unit costs "level out" is about 700-800 rental acres as compared to about 600-700 owned acres. (2) Total costs per dollar of output (total revenue) for rented land are about ten cents less than for owned land at comparable levels of total revenue. Part of this ten cent difference arises from the fact that, under existing leasing arrangements, the tenant pays less per acre to the landlord in share rent than his land costs per acre would be as an owner. For example, assuming the "standard" Budget I crop rotation, an owner-operator's land costs per acre are $56 ($800 land @ 6% = $48 plus $8 land taxes), while the tenant pays the landlord the equivalent of only $47 per acre in share rent. Under these conditions, tenant profits are $9 per acre higher than an owner-operator; profit and total revenue per dollar of cost are also higher.

These results indicate that: (1) Landlords renting out land on a cash or share-rent basis (or owner-operators) ordinarily are receiving less than a market rate of return on their investment (based on present land prices and interest rates). (2) The discrepancy between owner land costs and tenant share rents becomes even grater as the rotation shifts to less intensive crops. Hence, owner operators with large acreages who are forced to farm less intensive crops may receive lower rates of return on their land investment than smaller operators farming more intensively. (3) Conversely, tenants expanding their operations may do so more profitably by

investing in additional machinery and renting land rather than "tying up" their capital in high priced land. These factors help explain the fact that most of the large farms in the area operate predominately rented land.

Cost Relationships under Optimum Farm Organizations (Linear Programming)

The product-mix assumptions used thus far are (1) a constant product mix for all size groups and (2) product mixes constant within but different between size categories. Linear programming is now used to derive cost functions which, under existing efficient technology for each crop, and within specified resources, rotation and institutional restrictions, represent minimum-cost mixes (cropping systems) for attaining each level of output (TR). This formulation measures cost relationships facing highly efficient farmers expanding their size of business within the realistic limitations facing them.

The linear programming analysis proceeds as follows: For each of the four typical machinery combinations, output (total revenue) is expanded in optimal fashion (least cost per dollar of output) by continuous increases in operating capital.[1] Ultimate expansion in each size group is limited by the power machinery available in critical time periods to perform field

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[1] Heady, E. O., and Wilfred Candler, op. cit., Chapter 7. Variable capital programming was used in deriving the greatest output (total revenue) per unit of operating capital (variable cost) at all cost levels. In this case, operating capital is used for fuel, oil, labor and associated variable inputs. A similar application is made by Barker, Randolph, Agricultural Economics Research, Vol. XII, No. 1, Jan. 1960, p. 6.

operations.[1] However, expansion must be consistent with the following specifications and restrictions:

(1) Rented land is composed of a typical 2:1 ratio of Yolo A (light-textured) soils to Yolo B (heavy-textured) soils.

(2) Nematode disease problems (and, secondarily, contract limitations and high risk) restrict tomato acreage to 25% (one year in four) or less on Yolo A land and 20% (one year in five) or less on the heavier Yolo B land.

(3) Also because of nematode problems, sugar beet acreage is restricted to 25% or less on both Yolo A and Yolo B land.

(4) Sugar beet acreage is restricted by a fixed government allotment for each grower. In accordance with sample information the sugar beet allotment is increased less than proportionately for each of the four farm size categories.

(5) A minimum of 25% of both Yolo A and Yolo B land is planted to alfalfa.

(6) The landlord requires that all rented land must be cropped; i.e., no land left fallow, although tomatoes can be subleased.

(7) The landlord requires a minimum of 20% of the rented land planted to the high value crops--tomatoes, sugar beets or some combination of the two.

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[1] Separate restrictions were used for tracklayers and wheel tractors since they generally perform different types of operations. The limited substitution possibilities between tracklayers and wheel tractors were ignored. For details of the procedure used in computing power availability and power requirements by crops, see page 25 and Table A-4.

Other restrictions (e.g., labor) might be imposed in certain cases. However, hired labor (primarily Mexican Nationals) is generally available to any single farm in essentially unlimited quantity at prevailing wages, providing the farmer arranges for them reasonably in advance. Rented land is not treated explicitly as a limitation. Additional land can usually be rented without difficulty providing the renter has a good reputation, pays prevailing rental rates and is willing to expand operations in a noncontiguous manner geographically. Increased costs associated with operations separated geographically are not explicitly introduced within each size category as size expands. However, in the larger size categories more equipment associated with a widely separated operation is included in the machinery inventory (e.g., carryalls, flat-bed trucks, etc.).

Linear programming is used to select the combinations and levels of 28 alternative crop activities which maximize total revenue per unit of cost, consistent with the above restrictions.[1] Figure 11 illustrates the resulting short-run total cost functions derived for each of the four machinery-size combinations. Total fixed cost (TFC) is, by definition, a constant for all levels of output in each of the short-run situations. Since all land is rented, total fixed costs include only fixed machinery costs. Total variable cost (TVC) for each level of output (TR) is derived directly by linear programming. Crops with the greatest revenue per dollar of variable cost enter the optimum plans at low output (TR) levels. As output (TR) increases and machinery capacity becomes restrictive, it is necessary to shift to crops providing lower returns per dollar of operating capital, but greater returns per hour of limited power equipment. Shifts to the lower value products causes output (TR) to increase at a decreasing rate, and therefore, TVC in relation to output to increase at an increasing rate (Figure 11).[2] Summation of TFC and TVC equals TC (total cost).

Figure 12 summarizes the average cost functions derived from the total cost functions of Figure 11. The derived short-run cost curves (I, II, III, IV) are "u" shaped because increasing AVC (average variable costs) eventually outweigh declining AFC (average fixed costs). Short-run curve IV lies on or above III over the entire output range, because (1) total and therefore average

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[1] For these optimum cropping systems and other details see: Dean, G. W. and H. O. Carter, Guides to Profitable Cropping Systems for Yolo County Farms, Giannini Research Report (forthcoming).

[2] It is emphasized that the increasing TVC in Figure 11 stems from the changing product mix. Under the linearity assumptions of linear programming TVC increases at a constant rate (constant AVC) if the product mix (rotation) is constant.

FIG. 11. TOTAL COST FUNCTIONS DERIVED BY LINEAR PROGRAMMING FOR EACH OF FOUR MACHINERY SIZE GROUPS.

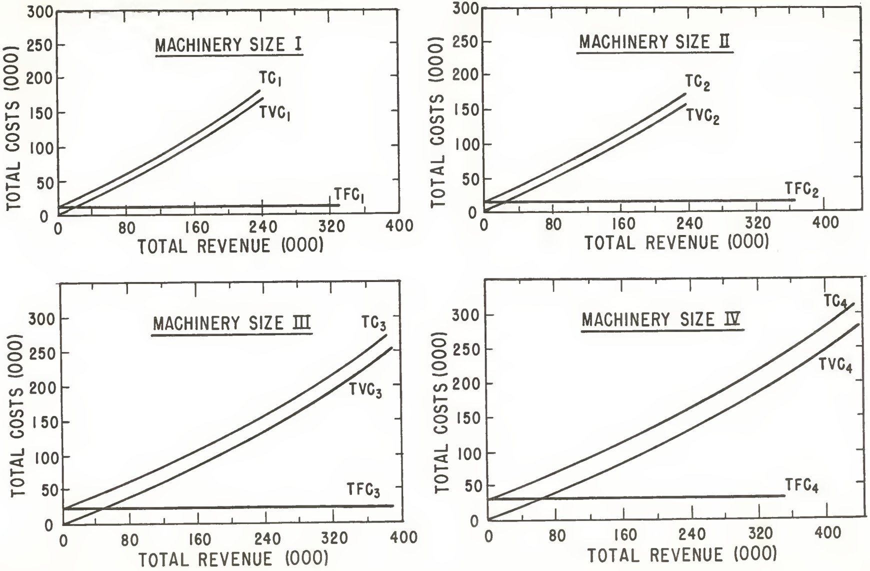
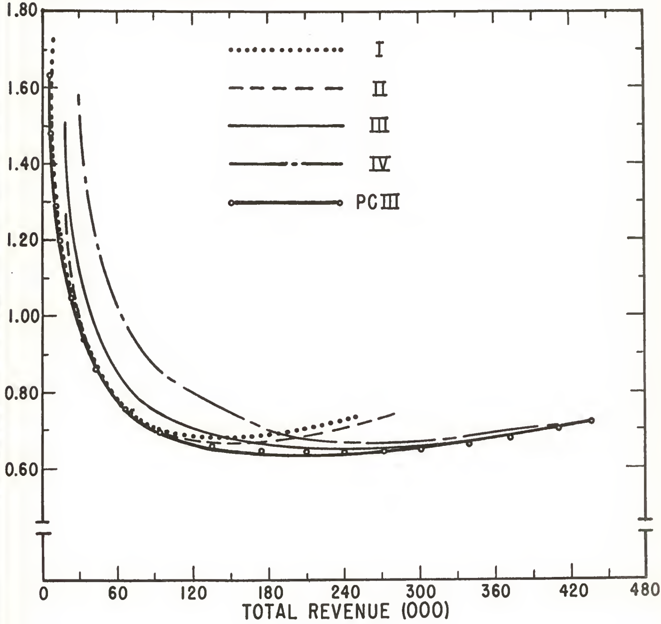


FIG. 12.

AVERAGE TOTAL COST CURVES FOR FOUR MACHINERY COMBINATIONS AND ENVELOPE OR PLANNING CURVE. (LINEAR PROGRAMMING)



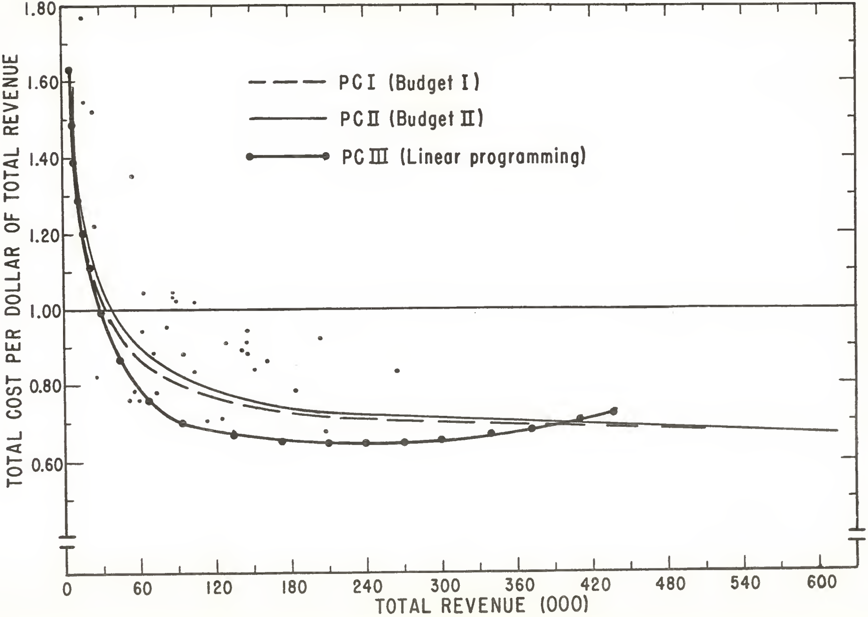
fixed machinery costs are considerably higher for machinery combination IV and (2) because the sugar beet acreage allotment does not increase proportionately with size. The envelope curve (PC III) is therefore "u" shaped, declining sharply to about \$0.70 at \$100,000 output, falling to a minimum of \$0.65 at \$240,000 output, then increasing gradually to about \$0.72 at an output of \$440,000. Thus, farms with output beyond \$240,000 (roughly 1,420 acres) begin to experience rising average costs because of the institutional and economic limitations forcing a change in product mix. This relationship may help to explain the absence of many farms actually operating in the extremely high output ranges.

Since a "u" shaped planning curve is seldom found empirically in agriculture or industry, the reasons underlying the shapes and positions of the cost curves have been explained in some detail. It is emphasized that the "u" shaped planning curve derived here relates directly to resource and institutional restrictions which change with size, forcing changes in input combinations and output mix. Nonetheless, the planning curve does correspond to a realistic path of expansion for farms in the study area.

Comparison of Budgeted and Programmed Costs with Sample Farm Observations.

The long-run average cost curves for share-renters based on three different sets of assumptions are superimposed upon the sample farm observations (Figure 13). The corresponding results for "owned land" were shown earlier in Figure 8. The three planning curves of Figure 13 represent approximations to the "true" planning curve facing share-renting operators in the Yolo area, based on different sets of conditions. Curve PC III represents the lowest possible cost (under existing technology, specified resources and the rotational

FIG. 15. COMPARISON OF PLANNING CURVES DERIVED BY BUDGETING AND LINEAR PROGRAMMING, ASSUMING SHARE RENTAL.



and institutional restrictions listed in the last section) for attaining each output (TR) level. Hence, this curve (connecting the "most efficient" points) should form an approximate envelope to the sample farm costs. Only four farms, all with output of less than $60,000, fall below the PC III curve. As pointed out earlier, these low-cost farms are employing more intensive rotations than could be sustained in the long-run.

As expected the programmed cost curve (PC III) falls below the budgeted cost curves (PC I' and PC II') over most of the relevant range, because the former is based on optimum cropping systems at each level of output. At high output levels, PC III rises above PC I' and PC II' for reasons noted above. Unfortunately, no farm observations are available beyond $270,000 to compare with the planning curves. This lack of actual farms beyond this point suggests that perhaps PC II' and PC III may be quite realistic; i.e., showing no great economies (even diseconomies in PC III) with further expansion. Again, risk and uncertainty become important considerations limiting expansion in this size range.

The observed individual farm unit costs are highly variable, particularly at output levels less than $60,000. However, only 12 share-rented farms are apparently operating with unit costs exceeding returns as compared to 16 owner-operated farms. This emphasizes the point that share-rental arrangements with typical cropping systems favor renters at present land prices.

As in the owned situation, renter costs as defined here include a market rate of return to the operator and to machinery investment. Hence, farm observations lying above the "break-even $1 line" are not necessarily incurring cash losses. They are, however, experiencing rates of returns on their resources below the market rate.

[illegible]

[illegible]

[illegible]

[illegible]

Summarizing, the data of Figure 13 indicate, both in terms of the analysis and actual farm observations, that: (1) share-renting with a gross income of less than $40,000 (about 200 acres) is not feasible with the usual cropping systems and costs found in Yolo County. Exceptions are renters who specialize in a high value crop such as tomatoes. (2) Per unit cost advantages for larger operations tend to diminish almost entirely beyond output levels of $140,000-$150,000. Further, it is possible that at extremely high output levels (beyond about $240,000), per unit cost may actually increase slightly, resulting from realistic limitations on farm expansion possibilities.

SUMMARY AND CONCLUSIONS

This report is the first of a series of studies for different farming areas of California, devoting primary attention to cost relationships as the scale of farming operations is expanded.

The report applies to the cash-crop irrigated area around Woodland in Yolo County, California.

A sample of 37 farms, ranging in size from 71 to 4,000 acres, provides the primary basis for the analysis. Cost relationships with respect to size are examined for both owned and share-rented operations under several different assumptions: (1) cropping systems expanded in constant proportions for all levels of output (TR); (2) crops expanded in nonconstant combinations "typical" of the sample of farms; (3) crops expanded in "optimum" combinations, using minimum cost per unit of output (TR) as the criterion of optimality. Budgeting provides the basis for (1) and (2) while linear programming is employed for (3). Above average technology and management are assumed throughout.

Briefly, the results can be summarized as follows: (1) Machinery costs per acre decline sharply up to about 600-700 acres, but only gradually (about $1.00 per acre for each additional 100 acres operated) thereafter. (2) If the same crop rotation is used for all sizes of farms, owner total costs per unit of output (TR) decline up to about 600-700 acres and then decline slowly throughout; renter costs decline substantially up to about 700-800 acres before tending to flatten out. (3) If larger farms must shift to less intensive crop rotations, owner costs per unit of output are nearly constant beyond 500-600 acres and renter costs per unit of output are nearly constant beyond 700-800 acres. In these cases, "smaller" ranches offset part of the cost economies of machine operations on larger acreages with a more

intensive cropping system. The results also suggest that share-renters capable of obtaining good quality land at going share rental rates may expand their operations more profitably by investing in the necessary machinery (or using present machinery more fully) and renting land rather than buying land at present prices. (4) If output (TR) is expanded in "optimum" fashion (rather than "typical") within realistic institutional and physical constraints acting in Yolo County, no cost advantages are evidenced beyond $240,000. In fact, per unit costs tend to increase beyond this level. Furthermore, the planning curve based on the "optimum" cropping system appears to form a reasonable approximation to an "envelope" of the actual farm observations, at least within the range where observations are available. This analysis assumes no economies in purchasing inputs (i.e., discounts on large purchases) or in marketing products in large quantities; however, no diseconomies of inefficient labor use or "red tape" are considered either. The shapes of the cost functions presented therefore arise entirely from other sources of economies and diseconomies, and would have to be modified if the omitted factors mentioned are important.

In conclusion, the analyses reveal definite economic reasons for the present trend toward consolidation and expansion in size of smaller units in Yolo County. On the other hand, the analysis does not indicate a strong economic incentive for expansion to extremely large size; farms of about 600-800 acres appear able to compete on a unit cost and profit basis with much larger farms. Yet because unit costs are approximately constant over a wide range, a continuation of a wide variation in farm sizes can be expected, with little tendency for farm size to concentrate at one "optimum" size.

The Yolo County area appears to be sufficiently representative of many other irrigated field crop areas of California and elsewhere in the West (in terms of types of crops, size of machinery and equipment, etc.), to suggest a similar pattern of cost relationships.[1] From a policy standpoint, the results clearly indicate the economic inefficiency associated with development programs limiting farm size in similar agricultural areas to 160 or 320 acres. If such size limitations appear desirable on social and other grounds, the sacrifice in efficiency should be clearly recognized.

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[1] Of course, cost relationships for farms raising fruits, nuts and other specialty crops undoubtedly are far different. Companion cost studies of important fruit and vegetable areas in California are now underway.

APPENDIX: SELECTED BASIC DATA

TABLE A-1. MOST COMMON LEASING ARRANGEMENTS IN YOLO COUNTY STUDY AREA

Crop	Share to landlord[a]	Cash rent	Shares used in budgeting and programming [b]
Tomatoes	15-20%	($60-80)	15%
Sugar beets	20%		20%
Alfalfa	25% (roadside)		25% (roadside)
Pink beans (single crop)	20-25%		25%
" " (double crop)	20%		20%
Safflower	25-30%		25%
Barley	25-40%		40%
Wheat	25-40%		40%
Milo (single crop)	25%		25%
" (double crop)	20%		20%
Corn	25%		25%
Sudan seed	25%		25%
Alfalfa seed	25%		25%

[a] Based on 1959 survey of 37 Yolo County farmers and on: Sample Costs of Production; Equipment Charges and Cost Estimates of Selected Crops, Woodland Area, Yolo County, 1958, Calif. Agr. Ext. Serv., Woodland, California, 1958.

[b] Assumes that landlord does no field work; tenant pays electricity for pumping.

TABLE A-2. PRICE ASSUMPTIONS FOR YOLO COUNTY CROPS [a]

Crop	Unit	% Sugar content	Price per unit
Tomatoes	ton		$22.00
Sugar beets	ton	16.0%	13.80
		15.7%	13.55
		15.0%	13.00
		14.7%	12.75
		14.0%	12.20
Alfalfa	ton		22.00
Pink beans	cwt.		6.50
Alfalfa seed (Buffalo & Ranger)	cwt.		27.00
Safflower	ton		75.00
Barley	cwt.		2.00
Wheat	cwt.		3.00
Milo	cwt.		2.10
Corn	cwt.		2.50
Sudan grass seed	cwt.		5.00

[a] Based on judgment and past prices received by Yolo County farmers.

TABLE A-3. PER ACRE YIELD AND FERTILIZATION ASSUMPTION FOR YOLO COUNTY CROPS a/

Crop		Soils					
		Yolo - A			Yolo - B		
omatoes b/	yield-tons	20	24		19	23	
	fertilizer	0	80#N 25#P_2O_5		0	80#N 25#P_2O_5	
ugar beets c/	yield-tons	17	22	25	17	22	25
	fertilizer	0	80#N	160#N	0	80#N	160#N
	% sugar	16.0	15.7	15.0	15.0	14.7	14.0
lfalfa d/	yield-tons	7.5			6.5		
	fertilizer	0			0		
ink beans	yield-lbs.	2200			1800		
	fertilizer	0			0		
lfalfa seed	yield-lbs.	500			400		
	fertilizer	0			0		
afflower	yield-lbs.	1800			2000		
	fertilizer	50#N			50#N		
arley	yield-lbs.	3400			2800		
	fertilizer	30#N			30#N		
heat	yield-lbs.	3000			2400		
	fertilizer	40#N			30#N		
ilo	yield-lbs.	5000			4000		
	fertilizer	125#N			125#N		
orn	yield-lbs.	6500			5500		
	fertilizer	150#N			125#N		
udan grass seed	yield-lbs.	2600			2200		
	fertilizer	50#N			50#N		

a/ All estimates except tomatoes and sugar beets based on estimates by Dr. Milton D. Miller, Department of Agronomy, University of California, Davis, and adjusted on the basis of "normal" yields estimated by a sample of 39 Yolo County farmers in 1958.

b/ Tomato estimates obtained from Dr. John Lingle, Department of Vegetable Crops, University of California, Davis. Tomatoes allowed one year in four on Yolo A soils, and one year in five on Yolo B soils.

c/ Sugar beet estimates obtained from Mr. Jack Hills, Department of Agronomy, University of California, Davis, and Mr. Dan Deter, Spreckles Sugar Company, Woodland, California. Sugar beets allowed one year in four on Yolo A and Yolo B soils.

d/ Four year stand assumed. Minimum of 25 percent of Yolo A and Yolo B soils assumed planted to alfalfa.

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[illegible]

[illegible]

[illegible]

[illegible]

TABLE A-4

Tracklayer and Wheel Tractor Power Availability and Per Acre Crop Requirements, by Time Periods[a]

Farm size equipment & time period	Per acre power requirements, by crops and time periods b/											Power available			
	To-mato	Sugar beets	Alfalfa hay	Pink beans	Alfalfa seed	Saf-flower	Barley	Wheat	Milo	Field corn	Sudan seed	Days avail-able for c/ fld.work	Tot.hrs. per tractor avail-able d/	Number of c/ tractors	Total tractor hours avail-able
SIZE I															
Tracklayer														2	
Sept.1-Oct.15	–	–	0.80	–	0.80	–	1.12	1.12	–	–	–	44	440		880
Oct.16-Feb.15	3.6	5.2	0.25	.7	0.25	1.5	.38	.38	.16	.32	.2	74	740		1480
Feb.16-May 1	–	–	–	3.4	–	–	–	–	.84	1.68	1.0	51	510		1020
Wheel tractor														2	
Sept.1-Oct.30	–	–	1.0	.4	1.0	–	–	–	–	–	–	59	590		1180
Nov.1-Feb.1	–	–	0	–	0	–	.5	.8	–	–	–	53	530		1060
Feb.1-Apr.1	1.7	1.2	–	–	–	.8	–	–	.4	–	–	34	340		680
Apr.1-30	–	.8	–	1.0	–	–	.2	–	.4	–	.3	24	240		480
May 1-31	.5	–	.7	.5	.7	–	.2	–	.25	.5	.3	29	290		580
June 1-30	.5	.4	.7	.8	–	–	–	–	.47	.17	–	30	300		600
July 1-31	.5	.4	.7	.8	–	–	–	–	.47	.17	–	31	310		620
Aug.1-31	.5	–	.7	–	–	–	–	–	.27	.17	–	31	310		620
SIZE II															
Tracklayer														2	
Sept.1-Oct.15	–	–	0.80	–	0.80	–	.9	1.0	–	–	–	44	440		880
Oct.16-Feb.15	2.9	4.4	0.25	.57	0.25	1.3	.3	.3	.13	.3	.17	74	740		1480
Feb.16-May 1	–	–	–	2.83	–	–	–	–	.67	1.5	.83	51	510		1020
Wheel tractor														2	
Sept.1-Oct.30	–	2.0	1.0	.4	1.0	–	–	–	–	–	–	59	590		1180
Nov.1-Feb.1	–	–	0	–	0	–	.4	.6	–	–	–	53	530		1060
Feb.1-Apr 1	1.3	1.0	–	–	–	.6	–	–	.4	–	–	34	340		680
Apr.1-30	–	.7	–	.9	–	–	.17	–	.4	–	.2	24	240		480
May 1-31	.5	–	.7	.5	.7	–	.17	–	.25	.5	.3	29	290		580
June 1-30	.5	.4	.7	.8	–	–	–	–	.45	.17	–	30	300		600
July 1-31	.5	.4	.7	.8	–	–	–	–	.44	.17	–	31	310		620

(Table A-4 continued.)

Farm size equipment & time period	Per acre power requirements, by crops and time periods b/											Power available			
	To-mato	Sugar beets	Alfalfa hay	Pink beans	Alfalfa seed	Saf-flower	Barley	Wheat	Milo	Field corn	Sudan seed	Days avail-able for c/ fld.work	Tot.hrs. per tractor avail-able d/	Number of c/ tractors	Total tractor hours avail-able
SIZE III															
Tracklayer														3	
Sept.1-Oct.15	–	–	0.50	–	0.50	–	.9	.85	–	–	–	44	440		1320
Oct.16-Feb.15	2.5	3.2	.15	.43	.15	1.1	.3	.25	.13	.22	.17	74	740		2220
Feb.16-May 1	–	–	–	2.17	–	–	–	–	.67	1.08	.83	51	510		1530
Wheel tractor														3	
Sept.1-Oct.30	–	1.1	.84	.4	.84	–	–	–	–	–	–	59	590		1770
Nov.1-Feb.1	–	–	0	–	0	–	.4	.6	–	–	–	53	530		1590
Feb.1-Apr.1	1.2	1.2	–	–	–	.6	–	–	.4	–	–	34	340		1020
Apr.1-30	–	.8	–	.8	–	–	.15	–	.4	–	.2	24	240		720
May 1-31	.5	–	.7	.5	.7	–	.15	–	.25	.5	.3	29	290		870
June 1-30	.5	.4	.7	.8	–	–	–	–	.42	.17	–	30	300		900
July 1-31	.5	.4	.7	.8	–	–	–	–	.42	.17	–	31	310		930
Aug.1-31	.5	.6	.7	–	–	–	–	–	.27	.17	–	31	310		930
SIZE IV															
Tracklayer														4	
Sept.1-Oct.15	–	–	0.50	–	0.50	–	.68	.82	–	–	–	44	440		1760
Oct.16-Feb.15	2.0	2.8	.15	.38	.15	1.1	.22	.28	.1	.22	.13	74	740		2960
Feb.16-May 1	–	–	–	1.92	–	–	–	–	.5	1.08	.67	51	510		2040
Wheel tractor														6	
Sept.1-Oct.30	–	1.1	2.25	.4	2.25	–	–	–	–	–	–	59	590		3540
Nov.1-Feb.1	–	–	0	–	0	–	.3	.4	–	–	–	53	530		3180
Feb.1-Apr.1	1.1	.75	–	–	–	.4	–	–	.4	–	–	34	340		2040
Apr.1-30	–	.55	–	.8	–	–	.14	–	.4	–	.15	24	240		1440
May 1-31	.5	–	2.1	.5	2.1	–	.14	–	.25	.5	.30	29	290		1740
June 1-30	.5	.4	2.1	.8	–	–	–	–	.41	.17	–	30	300		1800
July 1-31	.5	.4	2.1	.8	–	–	–	–	.41	.17	–	31	310		1860
Aug. 1-31	.5	.6	2.1	–	–	–	–	–	.27	.17	–	31	310		1860

(continued on next page.)

(Table A-4 continued.)

a/ A. D. Reed and P. S. Parsons, Extension Economists, University of California, Davis, assisted in estimating time periods for individual field operations for each crop.

b/ Based on numerous California Extension Service publications pertaining to different crops. Calculated on an engineering efficiency basis.

c/ See Table 4 for sizes of power equipment.

d/ Based on a 10-hr. day.